

R&D

Research & Development

MARKET FOCUS

**1991 Spending Forecast—
\$158 Billion and Holding**

Page 38

**Plastics Grown in Bacteria
Inch Toward the Market**

Page 46

TECHNOLOGY SPOTLIGHT

Why HPLC Keeps Growing

Page 54

PRODUCT APPLICATIONS

**NMR Spectroscopy Advances
Biotechnology Research**

Page 60

How to Select a Microscope

Page 66

OPTICAL COMPUTING

AT&T Bell Labs' Alan Huang

Page 32



Diamond Films, page 23

R&D FOCUS

Optical Computing At a Crossroads 32

Two U.S. researchers say they can build an optical computer. They disagree on the best way to do it.

\$158 Billion and Holding for U.S. R&D in 1991 38

Fears of recession, the budget deficit, and Saddam Hussein make real growth in R&D spending unlikely this year.



Optical Computing, page 32

DEPARTMENTS

IN BRIEF 5
Research thwarts student development.
Radioactive liquid waste put to rest.

EDITORIAL 15
Let's declare 1991 'The Year of Science
& Math Education'

BUSINESS 19
More restructuring needed to offset high
pharmaceutical R&D costs. Slow growth
for GC systems.

NEWS 22
Japan eyes U.S. civilian aviation lead.
'New chemistry' overcomes problems of
diamond films. Scientists find a buildup
of hydrogen in the atmosphere.

INDUSTRY EVENTS 31

NEW PRODUCTS 78

PRODUCT CENTER 86

LITERATURE 89

ADVERTISERS INDEX 93

READER SERVICE CARD 95

Plastics Grown in Bacteria Inch Toward the Market 46

Polyester resins made by bacteria offer biodegradability and purity.
The problem is they're still pricey.

TECHNOLOGY SPOTLIGHT

HPLC Keeps Growing Among the Separation Sciences 54

Among chemists, high-performance liquid chromatography is the clear
leader in chemical analysis methods.

PRODUCT APPLICATIONS

NMR Spectroscopy Advances Biotechnology Research 60

NMR is helping researchers working on new pharmaceuticals, heavy metal
toxicology, and agricultural biotechnology.

How to Select a Microscope: Upright or Inverted? 66

There are advantages and disadvantages to each type, depending on the
application you're working on.

'Vacuum Industry Needs to Broaden Its Scientific Base' 73

Mars Hablanian says the vacuum industry will do itself a favor by ex-
panding beyond the semiconductor industry.

ABOUT THE COVER Alan Huang
demonstrates AT&T Bell Lab's proto-
type digital optical computer, which op-
erates with light instead of electricity.
Photo courtesy AT&T Bell Laboratories.

R&D BUSINESS

More Restructuring Needed to Offset High Pharmaceutical R&D Costs

"Rising R&D costs and generic substitution of prescription drugs will force more pharmaceutical companies to merge in the 1990s," says Mason ("Skip") Irving, manager of Arthur D. Little's Health Care practice.

"The pharmaceutical industry is quite fragmented," says Irving. The 10 largest companies in the world only have 20% of the market, a ratio that is well below that of other industries.

The main problem is rising R&D costs and their effect on profitability. A pharmaceutical firm can take eight to 12 years to develop one new drug, while incurring development costs of

up to \$200 million. Over the past 10 years, pharmaceutical firms have had to increase their R&D spending from 11% of sales to more than 16% of sales to offset these cost increases.

A company might not have very long to make up those costs. Since most drug patents are filed five to six years into development, a marketed drug has only five to eight years of patent exclusivity before generic substitutes can be introduced.

In most cases, the generic substitute will take away more than half of a drug's market within three years of the generic's introduction.

Given these economic realities, fewer drugs will be profitable than have been in the past, says Irving.

"Pharmaceutical firms are changing the way they do their R&D," he says. "They're planning product development in a much more structured manner than before."

Product managers now not only have to decide which drugs should be developed, but also how they are going to be positioned and how much

Increasing development costs for new ethical drugs, which can exceed \$200 million per drug, will force a shakeout of marginally profitable pharmaceutical firms.

Top 10 Drug Companies

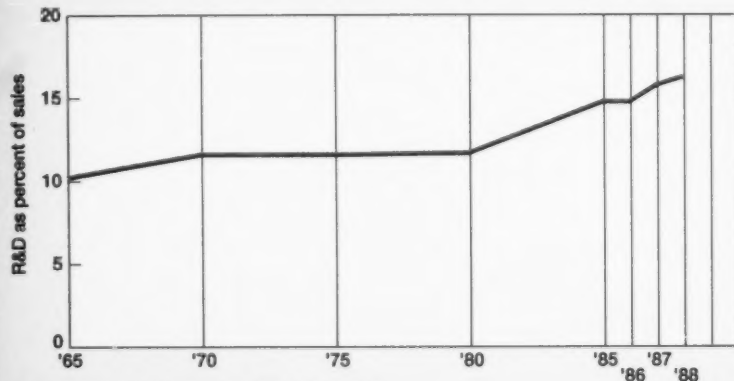
1989 sales*

1	Merck	5.4
2	Bristol-Myers Squibb**	5.2
3	Glaxo	5.0
4	SmithKline Beecham**	4.4
5	Hoechst	4.4
6	Bayer	4.0
7	American Home Products	4.0
8	Ciba Geigy	3.9
9	Takeda	3.9
10	Sandoz	3.5

*Billions of U.S. dollars

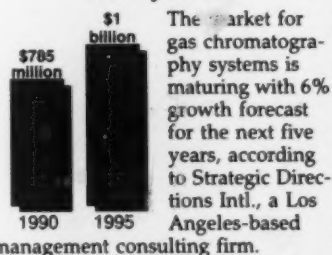
**Recent restructuring

Skyrocketing drug R&D costs will force more restructuring



Source: Pharmaceutical Manufacturers Assn.; Arthur D. Little

Slow Growth for GC Systems



Over the next several years, the U.S. Environmental Protection Agency is expected to approve HPLC for several environmental test methods, which will replace many existing GC methods and cut into the GC instrument growth.

patent life they will have.

But just changing the way R&D is performed won't be enough to change the overall economics. More restructurings are essential to fund the level of R&D that is necessary.

Only a few pharmaceutical firms have merged so far, including SmithKline Beecham, Bristol-Myers Squibb, and Marion Merrell Dow. As a result of future mergers, Irving predicts that the 10 largest pharmaceutical firms in the year 2010 will have nearly 40% of the market, a number that should justify the large development costs of new drugs.

—Tim Studt

Commerce Dept. Opens Clearinghouse for Technology Ideas

Information from more than 700 local, state, and federal technology programs and from more than 400 individuals working on technology programs is available in a database from the U.S. Dept. of Commerce.

The DOC's recently announced Clearinghouse for State and Local Initiatives on Productivity, Technology, and Innovation classifies programs in 12 categories, including financial and technical assistance. For more information, call 202/377-8100.

R&D

Japan Eyes U.S. Civilian Aviation Lead

An offer to the world's most advanced airplane engine manufacturers to join a Japanese-led supersonic propulsion development program has Western aviation companies sitting on edge.

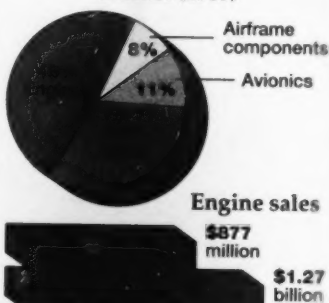
At stake is a possible piece of the pie for next-generation supersonic transport aircraft, funding commitments for advanced programs, and lucrative footholds into Pacific Rim markets. But these plums will not come without a cost, which could include transfer of technology that the West (particularly the U.S.) has built up in civil aviation since World War II.

"We are not convinced that working with the Japanese is a bad thing," says Bill Robeson of the Aerospace Industries Assn., a Washington, DC, trade group. "But, the Japanese are very competent at making use of the technology that they acquire."

The invitation to participate, the first ever made by Japan's Ministry of International Trade & Industry (MITI) to foreign companies, is designed to give Japan a head start on technology for supersonic/hypersonic propulsion.

As airplane market grows, so will competition

Airplane component market (1989)



Source: Freedonia Group Inc.

The civilian airplane market will grow to more than \$27 billion by 1994, according to the Freedonia Group, Cleveland. U.S. sales and exports of engines and parts will rise to almost \$1.3 billion by 1994, averaging about 8% growth per year.

The invitation was made to General Electric's Airplane Engine Div., Evandale, OH; Pratt & Whitney, East Hartford, CT; Rolls Royce Industries, Ltd., Derby, England; and Snecma, Paris. They would work with Ishikawajima Harima Heavy Industries Co., Mitsubishi Heavy Industries Ltd., and Kawasaki Heavy Industries Ltd. to research, build, and test ramjet and turbojet engines for a Mach 5 transport.

Officials at Rolls Royce say they are close to agreement on their part of the \$220 million 8-year program.

"We know there will be some tech transfer, but for the area we will be working on (emission systems) it will be beneficial for us," says Brian Lowrie, chief engineer of high-speed propulsion at Rolls Royce.

NASA recently began a high-speed civil transport program, which is aimed at developing technology for a Mach 2.5 to 3 transport. GE and Pratt, traditionally fierce competitors, have teamed up to work in that program.

Some market forecasts project a need for a next-generation supersonic airplane that could cut the travel time from Los Angeles to Tokyo from 10 hours to four.

"In aeronautics, it's economic suicide not to pursue an [SST] project," says Norris Krone, executive director of the Maryland Advanced Development Lab, Greenbelt, MD. "If our engine makers do not get involved in this project, and the NASA project does not take off, then we are really out."

So far, GE and Pratt have kept quiet about the MITI proposal, only saying that they are negotiating terms of participation. Industry experts agree that attention to detail will be the key to any agreement with MITI.

"I don't think there is an innate discomfort in dealing with the Japanese or the Europeans in principle," AIA's Robeson says. "But the devil is in the details."

"It's a big world out there," adds Krone, who has testified to Congress concerning the FSX fighter controversy. "If we don't take part [in the MITI project] other people will."

—Skip Derra

Technicians at NASA's Lewis Research Center, Cleveland, install instrumentation on a Mach 5 engine inlet model prior to wind tunnel testing. Japan has invited two leading U.S. engine manufacturers to help them develop advanced propulsion systems and get their fledgling SST project off the ground.

\$158 Billion and Holding For U.S. R&D in 1991

Fears of recession, the budget deficit, and Saddam Hussein make real growth in R&D spending unlikely this year.

By Tim Studdt, Associate Editor, R&D Magazine



Caution is a word that most R&D budget managers are using this year when they describe their 1991 R&D budgets. Fears of a large recession, tight money policies, escalating government deficits, and increasing costs resulting from the Mideast crisis have R&D managers wondering if their R&D funding sources will hold up throughout 1991.

If a recession hits too deeply, industrial research managers might have to balance corporate profitability against their R&D budgets—and that means less money for R&D. Government re-

search managers also wonder if the U.S. Department of Defense (DOD), the largest single research funding source, will cut back on R&D contracts to pay for the Desert Shield buildup. This leaves university R&D managers caught in the middle, wondering if their industrial and government funding sources similarly might soften.

It is in this context that *R&D Magazine* forecasts that Federal, industry, and university and nonprofit research funding sources will spend \$158 billion in 1991. This is a 5.3% increase over the \$150 billion in research expenditures that the U.S. National Science Foundation indicated would be spent in 1990.

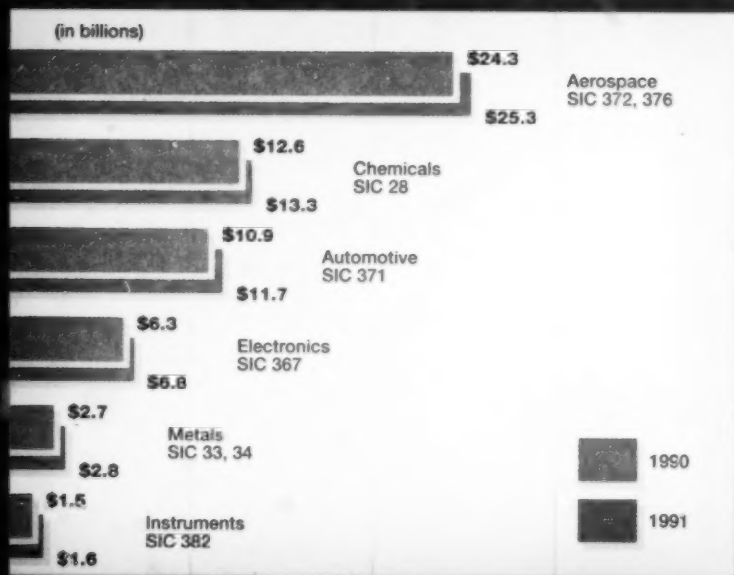
But, after you factor in the current inflation rate, this indicates that research spending will continue in 1991 at the same or even a slightly lower rate than that of 1990.

Cahners Economics, Newton, MA, forecasts a 5.0% increase in the 1991 consumer price index. However, for the past 12 months the CPI has been running at 5.5%, up from 4.4% for the previous 12 months, and energy costs could increase these rates even further if the Mideast crisis escalates. Economic analysts are modifying their forecasts almost daily in an effort to keep up with changing economic and political conditions.

An additional economic factor is that research costs normally escalate at a rate that is about one percentage point higher than the CPI.

"The higher education price index, an index that tries to estimate the cost of institutional purchases, has always run about 1% higher than the CPI," says Roland Schmitt, president of Rensselaer Polytechnic Institute, Troy, NY. "If you ask industries about their research costs, they would probably

Slow growth of R&D in key industries



Industrial research in 1991 will have smaller increases than in 1990, often several percentage points lower and sometimes not matching inflation increases, such as those in aerospace (4.2% increase) and metals industries (3.7% increase).



U.S. R&D to reach \$158 billion in 1991

Who pays for U.S. R&D



Research funding sources will increase their monies in 1991, but will monitor the economy throughout the year and make adjustments down each month or quarter if necessary.

Who does the work



University research centers will increase their share of the total research workload, but they will see smaller growth (9.1%) than in the past two years (10.4% average growth).

'We try to keep a steady investment in research, rather than jerk it up or down,' says IBM's Marc Brodsky.

be 1% above the CPI also."

There is the possibility that university research costs might even increase beyond this level (see box).

Research funding and spending in 1991 will follow similar patterns to those in previous years. The Federal government and industry will provide more than 95% of the funds, but Federal labs will perform only 11% of the work, while industry will perform 71.5%. Both these performance shares are down slightly from 1990 shares, as university and nonprofit research pick up more work for a 17.4% share, up more than a half percentage point from 1990.

Industrial uncertainties

Most companies are holding their 1991 R&D expenditures to 1990 levels or adding only slight increases, after adjusting for inflation. "When the Washington, DC-based Industrial Research Institute surveyed its members recently, "an overwhelming number of respondents indicated they expect to maintain or slightly increase their R&D budgets in 1991," says Philip

Brodsky of Monsanto, chairman of the IRI's research committee.

Companies that grew during the fierce competitive and takeover pressures of the 1980s feel they are in a fairly strong position today with confidence in the competitive technology of their products.

Research managers realize that foreign competitors in Japan and Europe are continuing their R&D spending, so they don't want to jeopardize their own competitiveness by cutting back too much on R&D.

Thomas Brick, president of Keithley Instruments, Cleveland, speaks for many industrial research administrators: "The very last thing I would do is cut back on my new product development, where I felt it would put me at a competitive disadvantage."

Moreover, most industrial companies have not seen any economic changes yet that would have an effect on their immediate research funding capabilities. Many companies have an increasingly strong export trade.

"However bad the overall economic news gets [about a recession], it will

not be as bad for industrial companies as it is for consumer companies," says Kermit Baker of Cahners Economics.

Big industrial R&D spenders, such as IBM, 3M, and Boeing, have the resources to ride out the first year of an economic slowdown. They continue to spend on R&D at the same rate as they have for the past few years.

"We try to keep a steady investment in research over the years rather than jerk it up or down," says Marc Brodsky, director of the technical staff at IBM Research, Yorktown Heights, NY.

Ronald Mitsch, senior vice president of R&D at 3M, St. Paul, MN, doesn't see any big changes either. "We've been spending about 6.5% of sales on R&D and we'll be continuing in that range [for 1991]," he says.

Despite severe cutbacks in major military programs, the aerospace division of Seattle-based Boeing will continue with its level of R&D spending in 1991, according to a Boeing spokesman. The commercial airplane division of Boeing has backlogs of airframe orders through the year 2000, which will support its R&D programs at their present rate.

Midsized companies don't have the same capability to ride out economic cycles as do large companies. But most of these companies also are not drastically altering their R&D budgets in 1991.

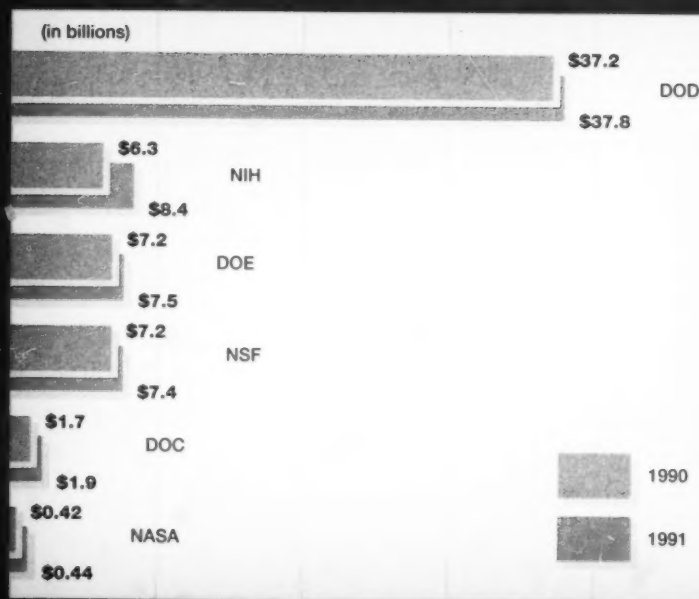
"So far our business is relatively good," says Alan Bennett, vice president of R&D at Varian Associates, Palo Alto, CA. "On the other hand, there are all these clouds on the horizon, and I'm sure that if things start to look bad, we'll batten down the hatches in R&D and in many other areas as well."

Some small companies often are unaffected by changes in the larger economy. "Our business has been anticorrelated with the macroeconomy," says Richard Blattner, vice president for Charles Evans Associates, Redwood City, CA. "Our research business through the Small Business Innovative Research (SBIR) program is expected to double next year."

"There appears to be a larger number of contracts being let at lower dollar amounts," he says. "Several government agencies have lowered the ceilings on these contracts to accommodate smaller budgets or to get more companies involved."

continued

Defense still dominates Federal R&D



Defense research continues to have the largest share of the federal budget, but its share will drop two percentage points in 1991, to 51.8%. Additional defense share decreases are forecast for the future as overall defense spending decreases and the research balance shifts to a more commercial-based emphasis.

'We're putting increased emphasis on shorter term research instead of blue sky efforts,' says Varian's Bennett.

Will the 1990s take the bloom off university research?

"I'm budgeting for much lower research growth in 1991—only 5%, compared to 15% growth in 1990," says R. and Schmitt, president of Rensselaer Polytechnic Institute, Troy, NY. "But, frankly I don't know how much credence to put into that."

This uncertainty for future funding sources faces many university research administrators. With smaller government and industry research increases and a recession almost assured, the double-digit growth that many university research administrators have enjoyed for the past few years seems to be a thing of the past.

In the past five years, while research at government and industry facilities grew by 8% in real dollars, research at universities grew by 28%, according to the National Science Foundation.

However, the very items that make university research attractive, that of lower costs and high-quality research, are being hurt by demographics and the technology itself.

"We see an extraordinary and un-

expected increase in the costs we expend to indirectly support research," says Judith Liebman, vice chancellor of research at Univ. of Illinois, Champaign. "The utility, health, and environmental safety costs of our research labs have increased far faster than the normal inflationary increases."

"Even library costs have gone

through the roof," says Liebman. "Foreign technical journals have increased 30% in price."

These costs are carried over to the research funding agency in the form of overhead. Univ. of California, Berkeley, actually had to forgo normal university overhead for its Sensor and Actuator Center so that it could receive NSF funding.

Possible shortages of researchers are another problem facing university administrators in the next decade.

In the 1980s, foreign PhD recipients who decided to stay in the U.S. after graduation made up much of the domestic shortfall in doctoral-level researchers.

"In some instances, these people are now going back home as their home country economies grow and improve," says Rensselaer's Schmitt. "Add to this the fact that there will be a large increase in the number of people retiring from science and engineering university faculties at the end of the decade, and I get a little apprehensive [about university research]."

Top 10 Schools For R&D Spending

(in millions)

Johns Hopkins Univ.	\$648
Massachusetts Institute of Technology	\$287
Cornell Univ.	\$287
Stanford Univ.	\$286
Univ. of Wisconsin, Madison	\$286
Univ. of Michigan	\$281
Univ. of Minnesota	\$259
Texas A&M Univ.	\$251
Univ. of California, Los Angeles	\$228
Univ. of Washington	\$222

However, the competition for these contracts has nearly doubled over the past five years as more people find out about them, according to Blattner.

Unusual government business

A strange thing happened at Georgia Tech, Atlanta, this past October. After having 10% to 15% growth in its research for the past 10 years, the income for new awards was down significantly from October 1989 levels.

"I called up several other universities to see if we had a particular problem," says Demetrius Paris, vice president for research and graduate programs at Georgia Tech. "What I found out was that a lot of Federal research funding agencies, not knowing how much money they had in the Congressional battle over funding the Federal deficit, did not make any awards during October 1990."

In the confusion, contracts were delayed, lost, or overlooked. Four million dollars promised to support a high-energy physics program at Fermi National Accelerator Laboratory, Batavia, IL, had to be hunted down at the last minute by U.S. Rep. Dennis

Hastert, the district's congressman, to avoid being lost.

"What we're seeing is an uncertainty and how long that is going to last is anyone's guess," says Georgia Tech's Paris.

The slowing economy, the saving and loan bailout, and Operation Desert Shield all will continue to add to the Federal budget deficit, which will bring about more such situations in the future.

For the time being though, government agencies are again funded and reissuing research contracts at a level that is as good as or better than that in 1990, except of course for defense research.

Smaller defense and defense research budgets, while still large, will result in at least a few corporate restructurings as defense contractors slash spending to survive lean times.

Changes in direction

Basic research makes up about 14% of the total amount of the U.S. R&D budget, of which 70% is performed in university and nonprofit centers, according to the NSF. Economic and

competitive pressures appear to be reducing this section in favor of more applied and development research.

"We're putting increased emphasis on shorter term research instead of blue sky efforts," says Varian's Bennett. "We made a decision to focus as much of our resources as possible to make Varian as profitable as we can, which we hope will create more money for R&D on a longer term."

Asked what specific challenges they have for the next 12 months, R&D managers overwhelmingly stated that managing the mix of projects that technology has made available is their biggest challenge. "You always have to advance specific technologies along a trend line," says IBM's Brodsky. "But you also have choose the right product from the technical opportunities that are out there."

R&D

READER RESPONSE PANEL

Please rate your interest in this article by circling the appropriate number on the Reader Service Card.

High 501 Medium 502 Low 503

Because semiconductors are at the low end of their cycle, the vacuum industry will be down 10% to 20%.

The semiconductor industry has driven vacuum manufacturers to achieve higher and higher levels of purity with its systems. This is part of one vacuum equipment trend that Hablani sees taking hold in the in-

dustry over the next five years.

The emphasis on particle-free environments is forcing systems designers to be more careful about the components they choose.

"Particles form by processes them-

selves, but they also form by pumps and valves and other components," he says. "All of the lines, all of the little fittings that are used in bringing a gas into the chamber, have to be relatively particle free.

"This is fairly serious in some cases and some vendors are seriously evaluating components before they choose them," Hablani says.

Another trend is toward ultrahigh vacuum. Hablani says the requirements for initial and process purity are driving companies in some cases to UHV systems.

"In other words, you have to get down to 10^{-9} torr before you can get into your process," Hablani says. "It puts a considerable amount of stress on the system and pump design."

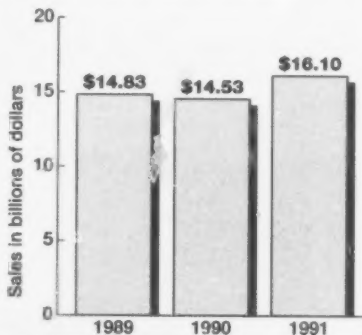
A third trend is in the use of oil-free pumps. Hablani says this trend goes in two directions.

"One is toward multistage root-blower type or similar systems, which essentially have no liquid oil in the

Slow growth predicted for semiconductor market

Semiconductor sales in the U.S. and Canada will rebound this year (+10.8%) after experiencing a slight downturn (-2.1%) in 1990, according to analysts at Cahners Economics, Newton, MA. While double-digit growth for the semiconductor industry is good, don't plan on seeing huge increases in the future.

"Business cycles for semiconductor sales will be muted in coming years," says Julie Handelman of Cahners Economics. Growth is expected, but you will not see a 30% gain in sales like what happened in 1988, she adds.



Forecasters: Cahners Economics
Source: Semiconductor Industry Assn.

Silicon

Ultra-high purity single or polycrystalline Silicon blanks, up to 22 inches in diameter, reflecting or transmitting mode. Both doped and undoped available for sputtering targets.

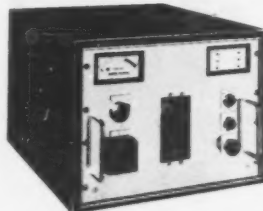
Silicon Casting Inc.

Sales: 1751 Saratoga Ave., San Jose, CA 95128-2733
Mfg.: 1000 Meridian St., Rancho Cordova, CA 95665-6521

For information circle 42

INDUCTION HEATING

SOLID STATE REPLACEMENT FOR TUBE OSCILLATORS
2½ KW TO 50 KW—30 KHz TO 200 KHz—STOCK DELIVERY



SOLID STATE ADVANTAGES

- COMPACT SIZE
- HIGH EFFICIENCY
- ELIMINATE POWER DRIFT
- SAFETY (LOWER VOLTAGE)
- LOW COST
- PROCESS REPEATABILITY

SEND PARTS FOR VIDEO DEMONSTRATION



IHS
AN INDUCTOHEAT COMPANY

5009 RONDO DRIVE, FORT WORTH, TX 76106
(817) 625-5577 • FAX (817) 625-1872

**Call IHS At 800-486-5577
or Fax Us For Immediate Information**

For information circle 43

